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A PARAMETRIC STUDY OF LONG RANGE ARTILLERY WEAPONS

F. J. John

Watervliet Arsenal

Prepared for:

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February 1975

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A study was made to determine the gun and ammunition characteristics of 155mm, 203mm and 240mm weapons having ranges of approximately 30 to 60KM. Results of many ballistic computations are tabulated and graphed.

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A PARAMETRIC STUDY OF LONG RANGE ARTILLERY WEAPONS

F. J. JOHN

U.S. ARMY ARMAMENT COMMAND

BENET WEAPONS LABORATORY
WATERVLIET ARSENAL
WATERVLIET, N.Y. 12189

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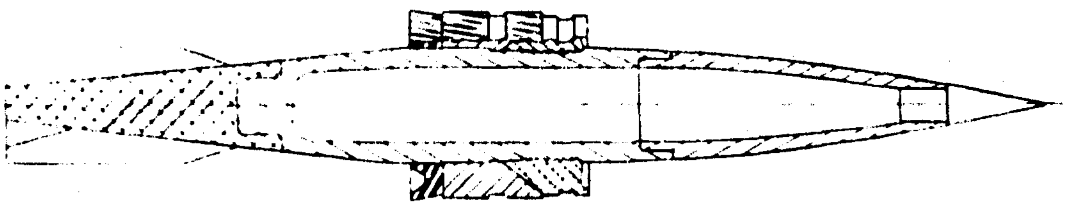
Introduction

This report describes a preliminary study of the characteristics of some artillery weapons with ranges in the 30 to 60 KM region. It was intended to determine if such ranges are feasible in weapons that are not excessively large or heavy. Another purpose was to produce an array of alternative weapons from which trade-off and other optimization studies can select the best for further development. The presented data is limited to the gun and ammunition. Although no vehicle characteristics are given, momentum values are provided and from these vehicle sizes may possibly be inferred.

The study was made for two reasons. First, there has been a noticeable change in attitude toward long range weapons. Past analyses have shown little need for ranges greater than those currently available. However, improved modeling and experience gained in recent wars show that there may be a place for longer range weapons after all. So, this study was made to see what these weapons would look like. The second reason was to take advantage of a new, low drag, finned projectile being developed at Picatinny Arsenal. This will provide longer ranges with much smaller increases in velocity, momentum and vehicle weight than those required by conventional projectiles.

The projectile is described in detail in Reference 1. It achieves lower drag through its shape and greater length/diameter ratio. It is nine calibers long and consequently must be fin stabilized. A 130mm version is now being fired to confirm flight predictions and to uncover potential problems. This design is shown in Figure 1; it has a sabot which is necessary for the experimental firings from a 203mm howitzer.

1. R. A. Reisman, J. S. Pordon, G. T. French, "The Potentials of Fin Stabilized Artillery Munitions," Report SAS 154, April 1973, Picatinny Arsenal.



FIN STABILIZED EXTENDED RANGE PROJECTILE

Figure 1

While the projectile can have a sabot in its ultimate use, this study is based on a full bore size projectile without a sabot. The methods of this study can be used with a projectile and sabot if necessary. It simply means recomputing the ballistics with slightly different input.

Objectives

Specifically, this study was intended to:

a. produce a large array of characteristics describing many long range weapons,

b. assess the feasibility of increasing artillery ranges without large weight and size increases,

c. make a preliminary selection of possible options for further study.

Scope

In order to make the study more manageable in this early phase, it was subject to the following limitations:

a. Only full bore projectiles were considered; that is, the projectiles had no sabots and the projectile diameter equaled the bore diameter.

b. Only the low drag, fin stabilized projectiles were considered. The ranges, pressure, etc., that result from the study apply only to these projectiles shown in Figure 1.

c. Three bore sizes were considered; these are 155mm, 203mm and 240mm.

d. Barrel lengths were limited to three values: 45, 50 and 55 calibers.

e. The study was limited to consideration of only the gun and ammunition, not the mount or vehicle.

Assumptions

The most important assumptions on which the study is based follow:

a. The propellant is multi-perforated M30

b. The chamber to bore diameter ratio is 1.2

c. $\text{Momentum} = \frac{4700C + Wp\ Vm}{g}$

Where C = propellant weight (lbs)

Wp = projectile weight (lbs)

Vm = muzzle velocity (ft/sec)

$g = 32.2\ \text{ft/sec}^2$

d. The density of loading is .60

e. The drag function for the projectile is that reported by R. Reisman in Reference 1

f. Projectile weights are: 125 lbs for the 155mm
200 lbs for the 203mm

both of which were furnished by R. Reisman. Two hundred sixty pounds for the 240mm was extrapolated from these values.

Results and Conclusions

a. Long range tube artillery with ranges of 40 to 50 KM are feasible within current system weight limits for air transportability.

b. A 155mm gun with a 45.5 KM range is definitely feasible.

c. A 203mm gun with a 45.5 KM range will be feasible if a momentum 25 per cent greater than that of current systems can be accepted.

d. More detailed characteristics of these 155mm and 203mm weapons are shown in the following Table 1:

1. R. A. Reisman, J. S. Pordon, G. T. French, "The Potentials of Fin Stabilized Artillery Munitions," Report SAS 154, April 1973, Picatinny Arsenal.

TABLE 1

SOME WEAPON CHARACTERISTICS

Bore Diameter (mm)	155	203
Barrel Length (calibers)	55	45
Max. Range (KM)	45.5	45.5
Max. Pressure (PSI)	50,000	50,000
Muzzle Velocity (FPS)	2,970	3,020
Momentum (lb-sec)	16,700	27,300
Charge Wt (lbs)	37.4	83.3
Muzzle Pressure (KSI)	9.2	7.5

e. Detailed ballistic output is tabulated in the Appendix, while most of that important data are graphed in Figures 5 through 13 in the Procedure section.

Procedure

Three bore diameters were selected to cover a reasonable range of values and to avoid a very large amount of computing. Since Picatinny Arsenal had designed some projectiles, they provided projectile weights for the 155mm and 203mm along with the drag function. A 240mm projectile weight was extrapolated to 260 lbs., and the muzzle velocity vs. range data were computed. The results appear in Figure 2.

During the range-velocity computation, an approximate range vs. momentum function was also computed for use in coarse estimating. This was done as follows: For each velocity and projectile weight combination, a charge weight was estimated from the muzzle energy and an assumed ballistic efficiency of 30 per cent. The momentum was then

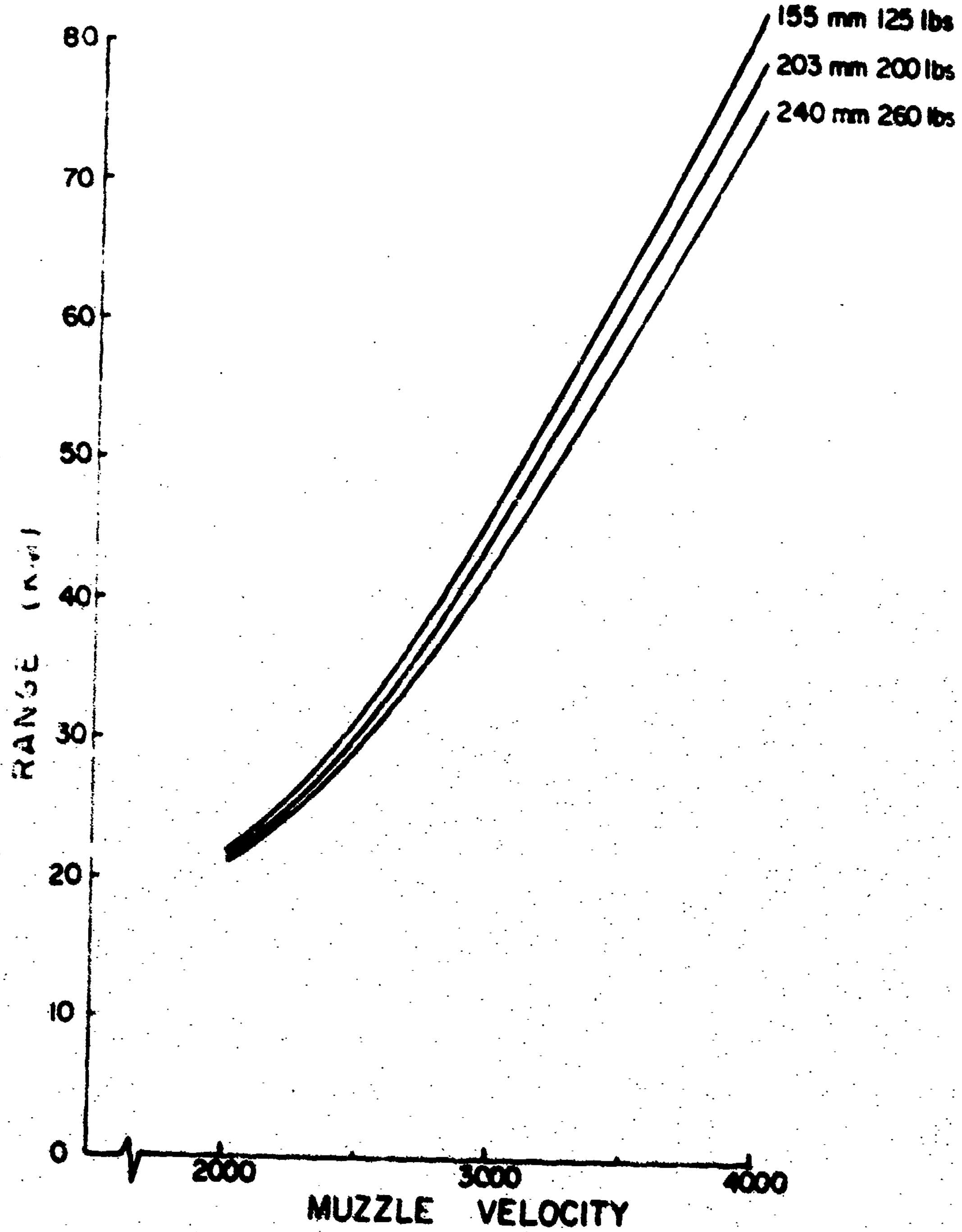

155 mm 125 lbs
203 mm 200 lbs
240 mm 260 lbs
80
70
60
50
40
30
20
10
0
2000
3000
4000
MUZZLE VELOCITY

Figure 2

computed along with the range; it is graphed in Figure 3. These curves actually represent bands rather than a single line since there can be variations in charge weight about the estimated values used in this computation. This can be seen by inspection of the more detailed results shown in Figures 5 through 13 and in the Appendix.

Next, interior ballistic computations were made to determine velocities for various combinations of gun and charge parameters. From these velocities and the velocity-range functions of Figure 2, the ranges for the various weapon combinations were found.

The combinations of gun-ammunition parameters selected for study are tabulated in Figure 4 as the X marked blocks. This involved 154 ballistic runs. The selected values for the parameters are reasonable for the weapons being studied. This can be seen by comparison with values for the same parameters in current and past weapons; some of these values appear in Table 2 for existing weapons.

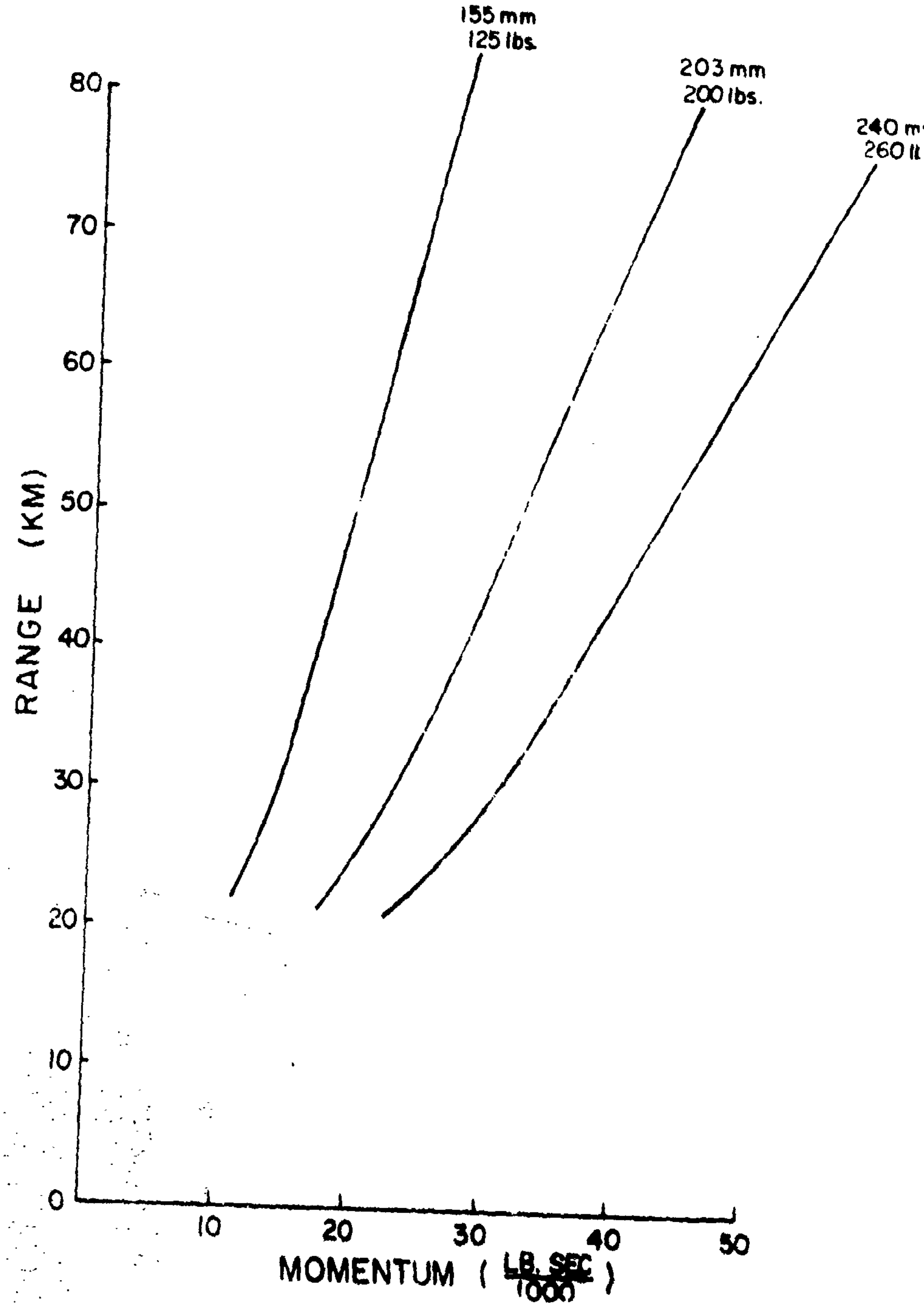

155 mm
125 lbs.
203 mm
200 lbs.
240 m
260 lt
RANGE (KM)
MOMENTUM (LB. SEC / 1000)
80
70
60
50
40
30
20
10
0
10
20
30
40
50

Figure 3

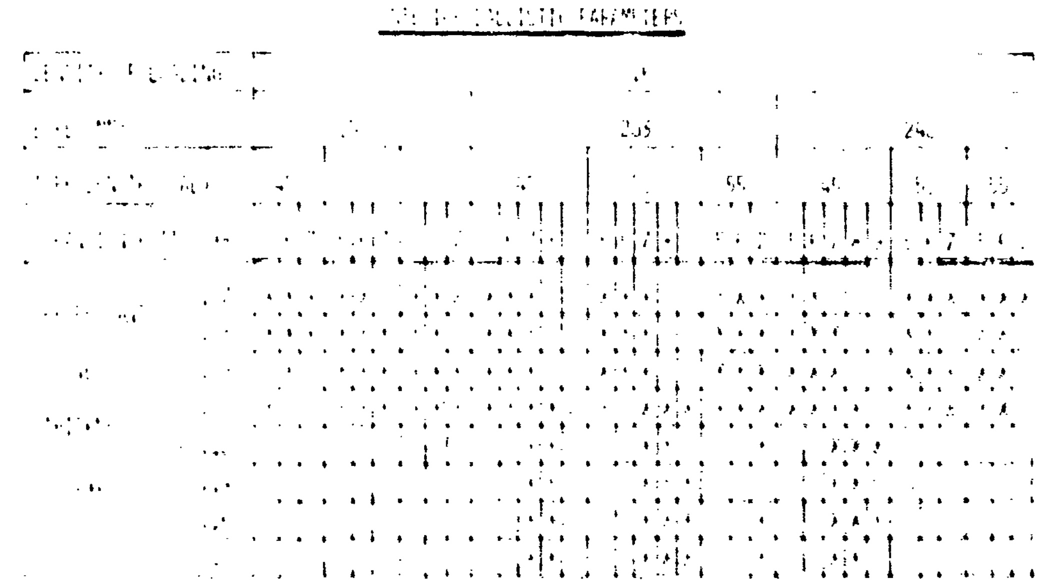


Figure 4

TABLE 2

PARAMETER VALUES OF EXISTING WEAPONS

WEAPON	BARREL LENGTH (CALS)	LOADING DENSITY	EXPANSION RATIO	MOMENTUM (LB-SEC)
105mm How M103		.51	9.2	2,075
M2A1		.51	8.6	2,000
105 Gun M68	50.5	84	7.2	
120 Gun M58	61	.78	5.25	
155 How M1		.46	5.2	
M126		.6	5.2	9,600
XM199	37	.49	6	9,600
155 Gun M2	44	.54	5.26	12,765
175 Gun	59	.53	5.53	22,120
8" How M2			8.5	
XM201	37	.62	8	22,120
8" Gun M1				34,710
240 How	31.5	.55	5.5	37,355
280 Gun M65	44	.48	5.6	69,490

The resulting ballistic output for the three weapon sizes appears in the Appendix. At first glance, this formidable amount of output makes interpretation appear difficult. Therefore, the more important data has been plotted and the resulting curves appear in Figures 5 through 13. These show relationships among range, momentum, maximum and muzzle pressures; they are shown as functions of the propellant web which was used as a source of variation. Several expansion ratios also appear on the graphs. This ratio is the gun volume/chamber volume ratio.

The curves can be used, and were used, to isolate weapons with selected constant values of any of the parameters. For example, a 50 ksi maximum pressure was selected along with 25,000 lb-sec maximum momentum in the 155mm and 35,000 lb-sec in the 203mm and 240mm. This produced a list of about 20 options from which the two shown in Table 1 of Results were selected. Of course, criteria other than the maximum pressure and momentum could have been applied and would have produced other lists.

Discussion

A minor part of this study was an attempt to estimate vehicle weight from a knowledge of the gun-ammunition data. Regression analyses were tried and were somewhat successful for only the towed systems. Data for self-propelled systems were scarce, and also the strong influence of automotive components on those vehicle weights precluded a curve fit. Although it is not likely that this study will be used for a towed system, the weight relationship is given below for information.

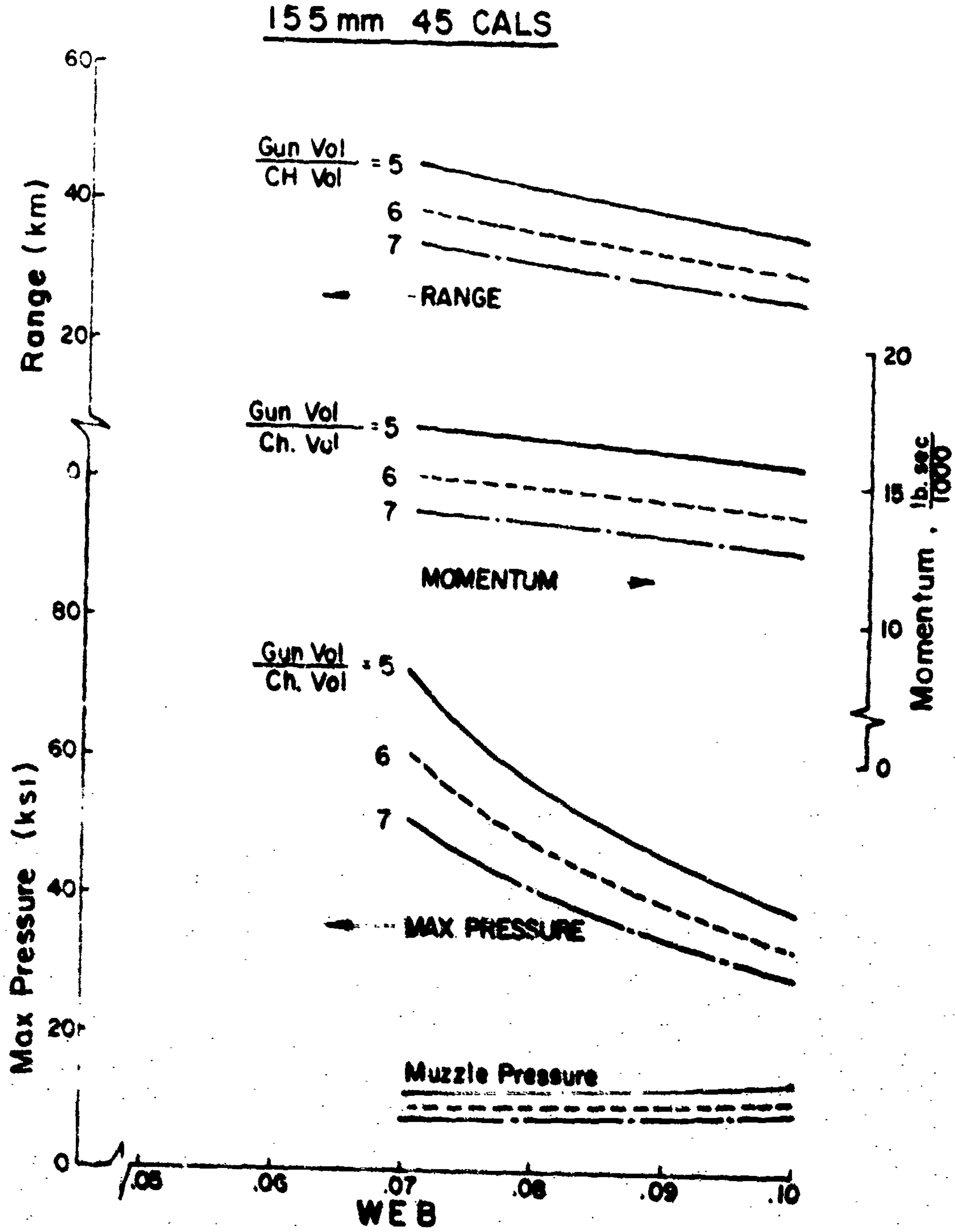

155 mm 45 CALS
Range (km)
Gun Vol / CH Vol = 5
6
7
RANGE
Gun Vol / Ch. Vol = 5
6
7
MOMENTUM
Momentum, lb.sec / 1000
Gun Vol / Ch. Vol = 5
6
7
MAX PRESSURE
Max Pressure (ksi)
Muzzle Pressure
WEB

Figure 5

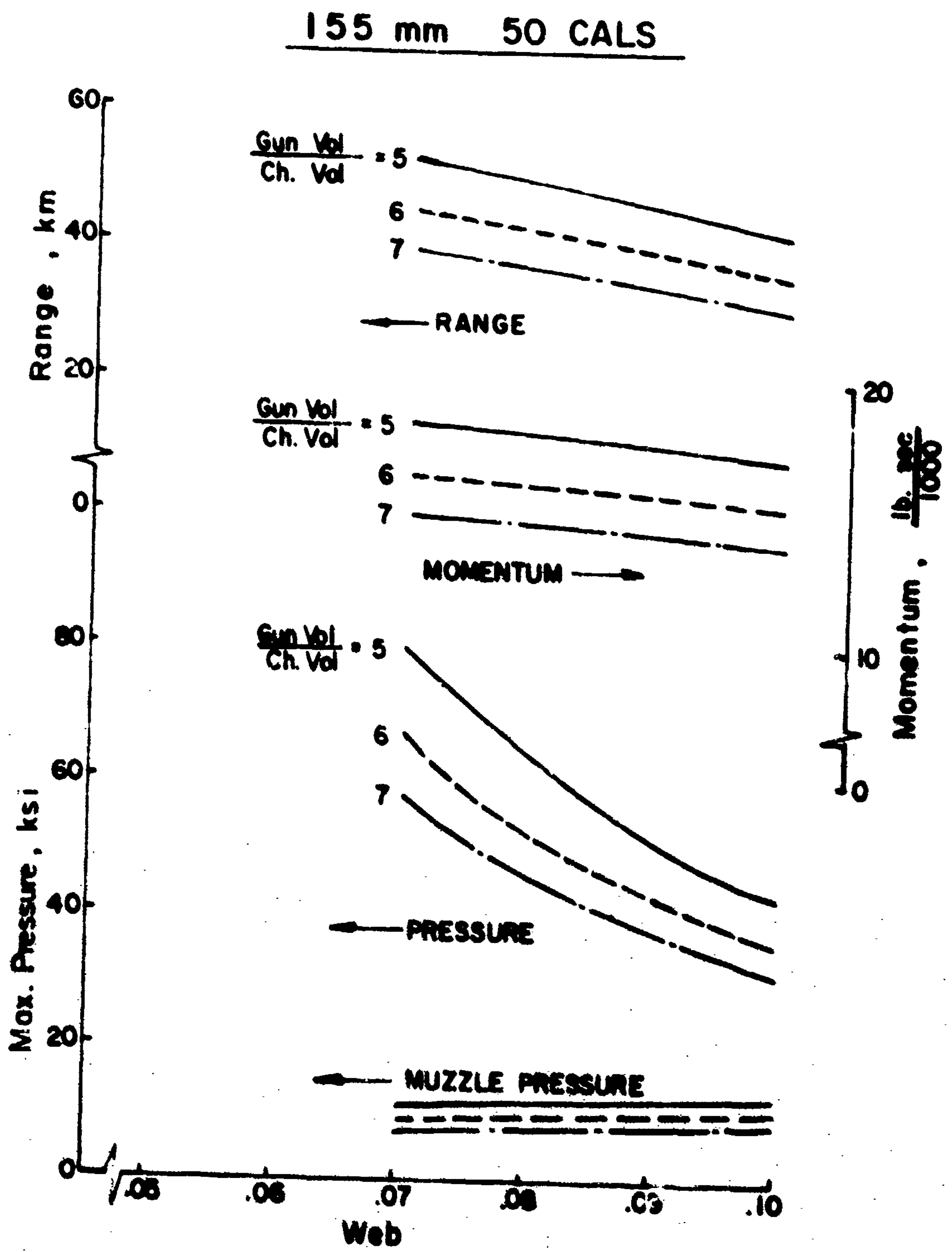
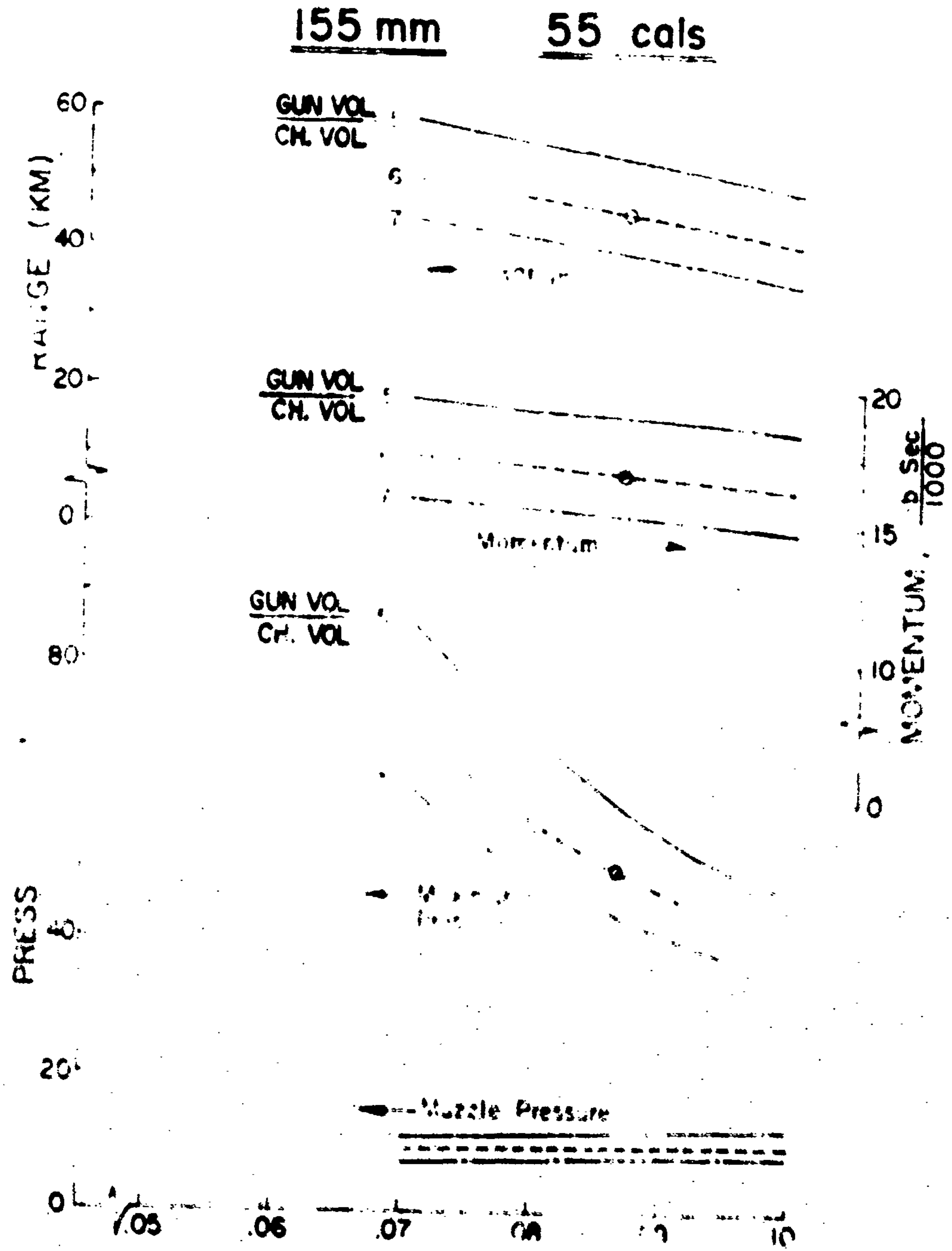

155 mm 50 CALS
Range , km
Gun Vol / Ch. Vol = 5
6
7
RANGE
Gun Vol / Ch. Vol = 5
6
7
MOMENTUM
Momentum , lb. sec / 1000
Gun Vol / Ch. Vol = 5
6
7
PRESSURE
MUZZLE PRESSURE
Max. Pressure , ksi
Web
60
40
20
0
80
60
40
20
0
20
10
0
.05
.06
.07
.08
.09
.10

Figure 6



155 mm
55 cals
GUN VOL
CH. VOL
RANGE (KM)
60
40
20
0
GUN VOL
CH. VOL
Momentum
MOMENTUM, lb Sec/1000
20
15
10
0
GUN VOL
CH. VOL
80
PRESS
40
20
0
Muzzle Pressure
.05
.06
.07
.08
.10

Figure 7

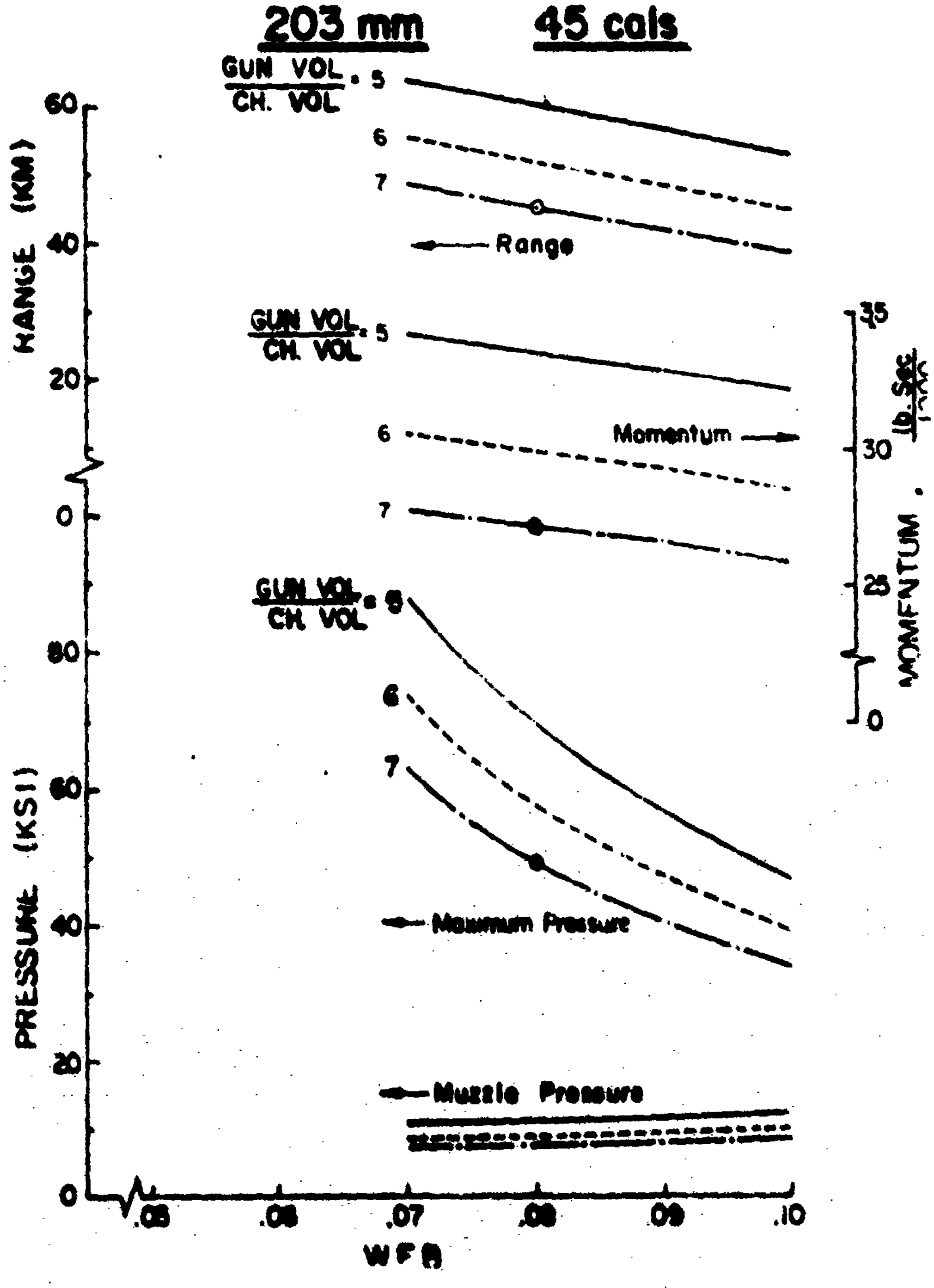

203 mm
45 cals
GUN VOL / CH. VOL = 5
6
7
Range
Momentum
Maximum Pressure
Muzzle Pressure
RANGE (KM)
PRESSURE (KSI)
MOMENTUM
0
20
40
60
80
25
30
35
.05
.06
.07
.08
.09
.10
WFR

Figure 8

203 mm 45 CAL

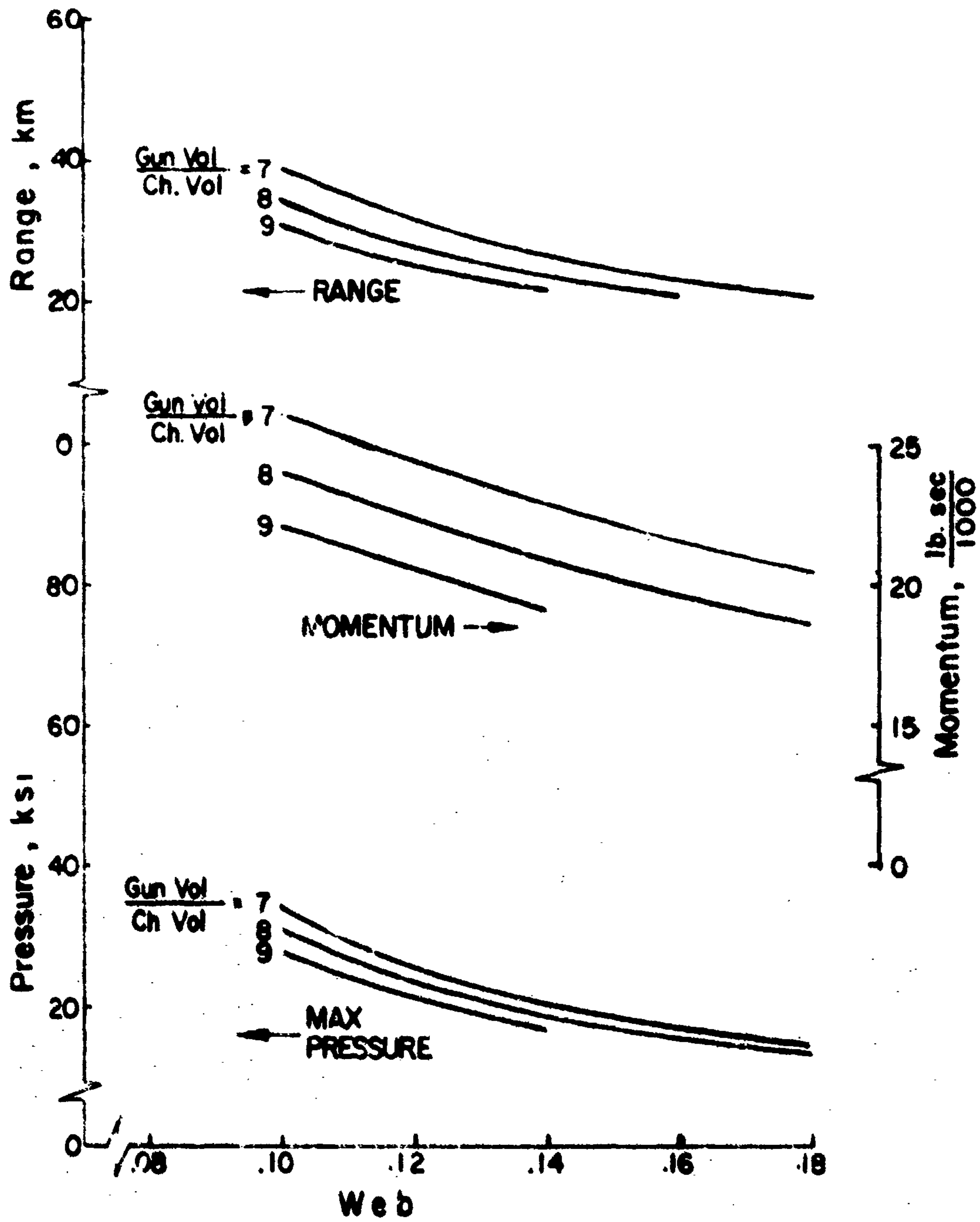
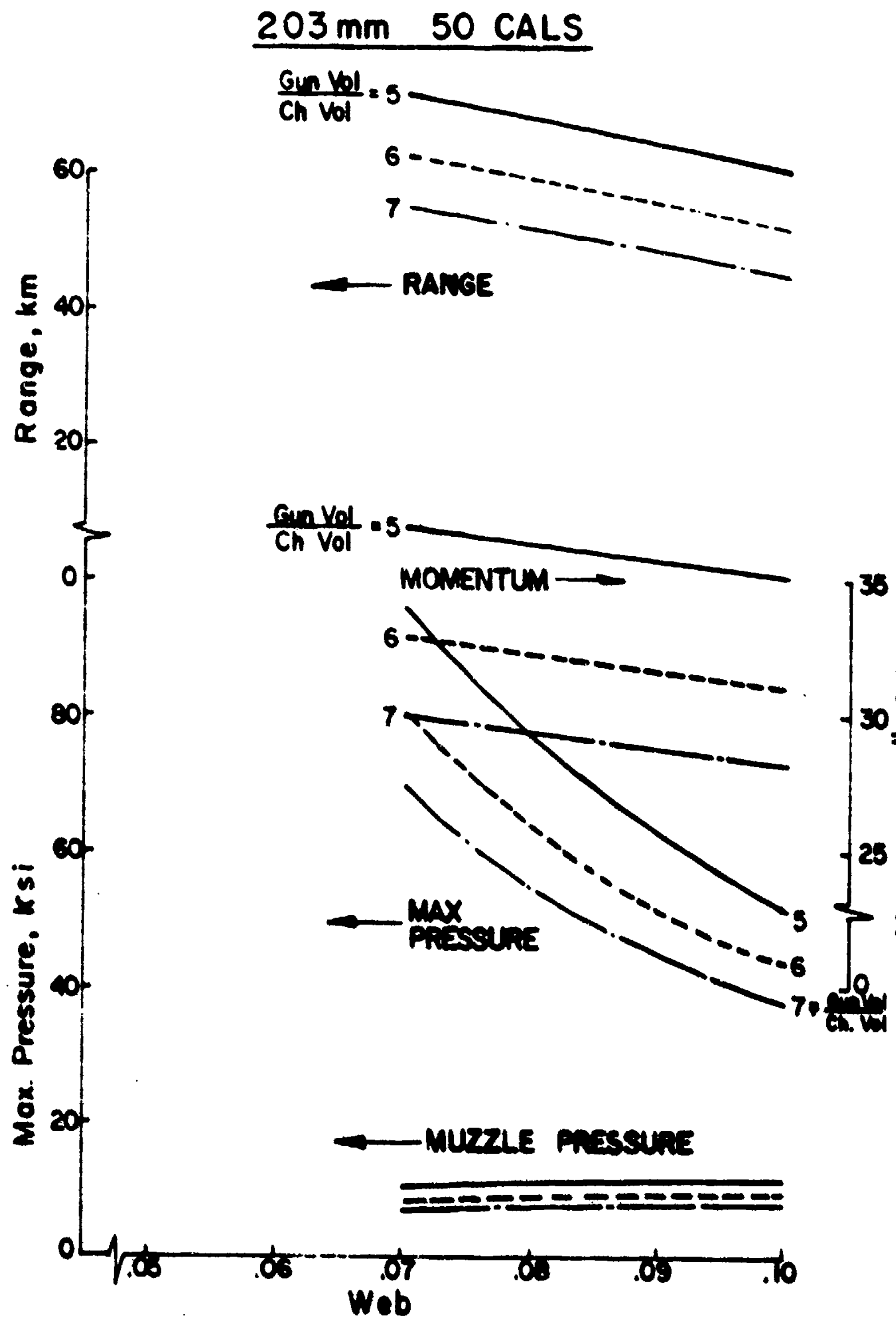


Figure 8 (continued)



203mm 50 CALS
Gun Vol / Ch Vol = 5
6
7
RANGE
Range, km
60
40
20
0
Gun Vol / Ch Vol = 5
MOMENTUM
6
7
80
60
40
20
0
MAX PRESSURE
Max. Pressure, ksi
MUZZLE PRESSURE
35
30
25
0
Momentum lb. sec / 1000
5
6
7 = Gun Vol / Ch. Vol
.05
.06
.07
.08
.09
.10
Web

Figure 9

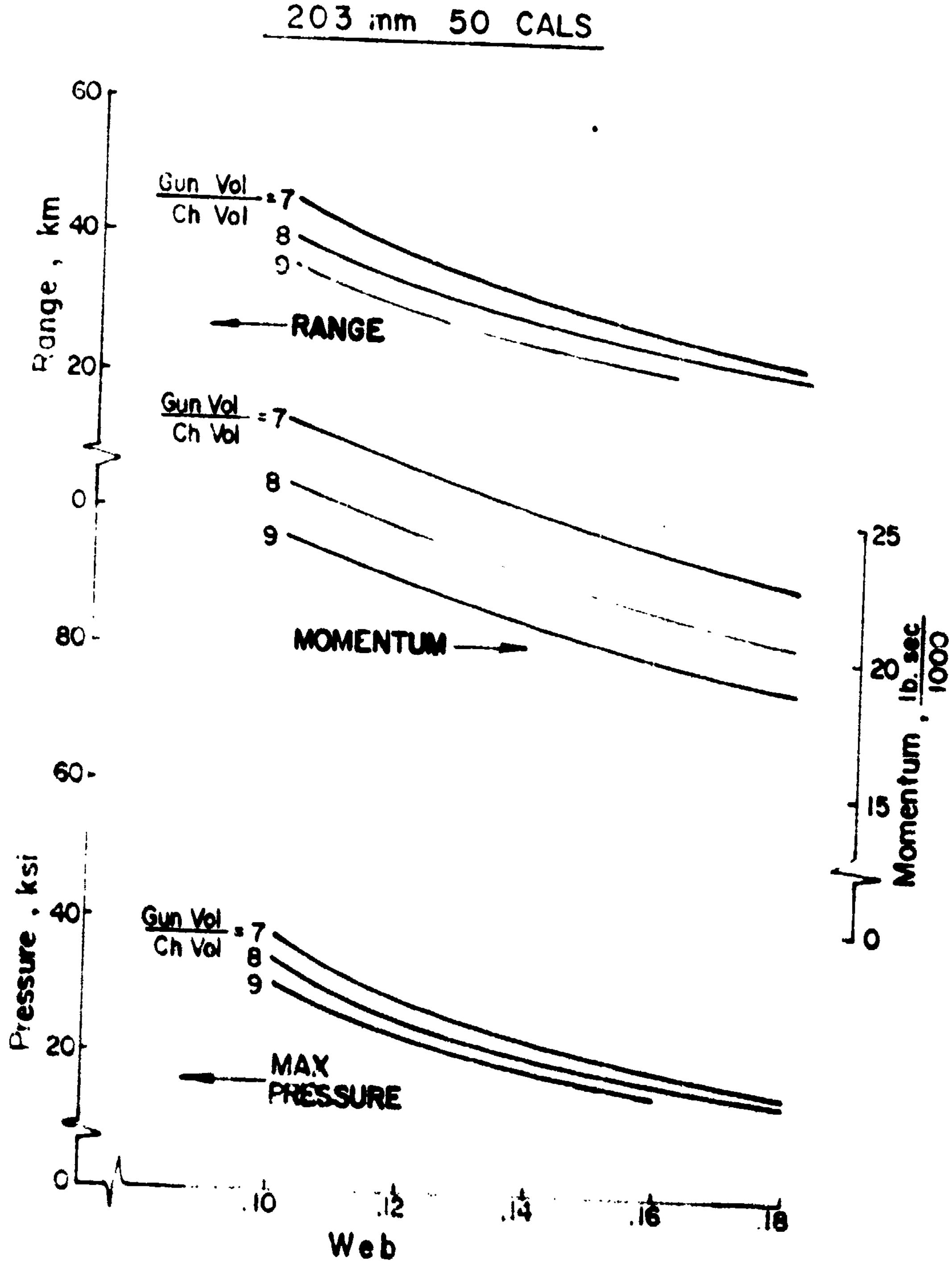


Figure 9 (continued)

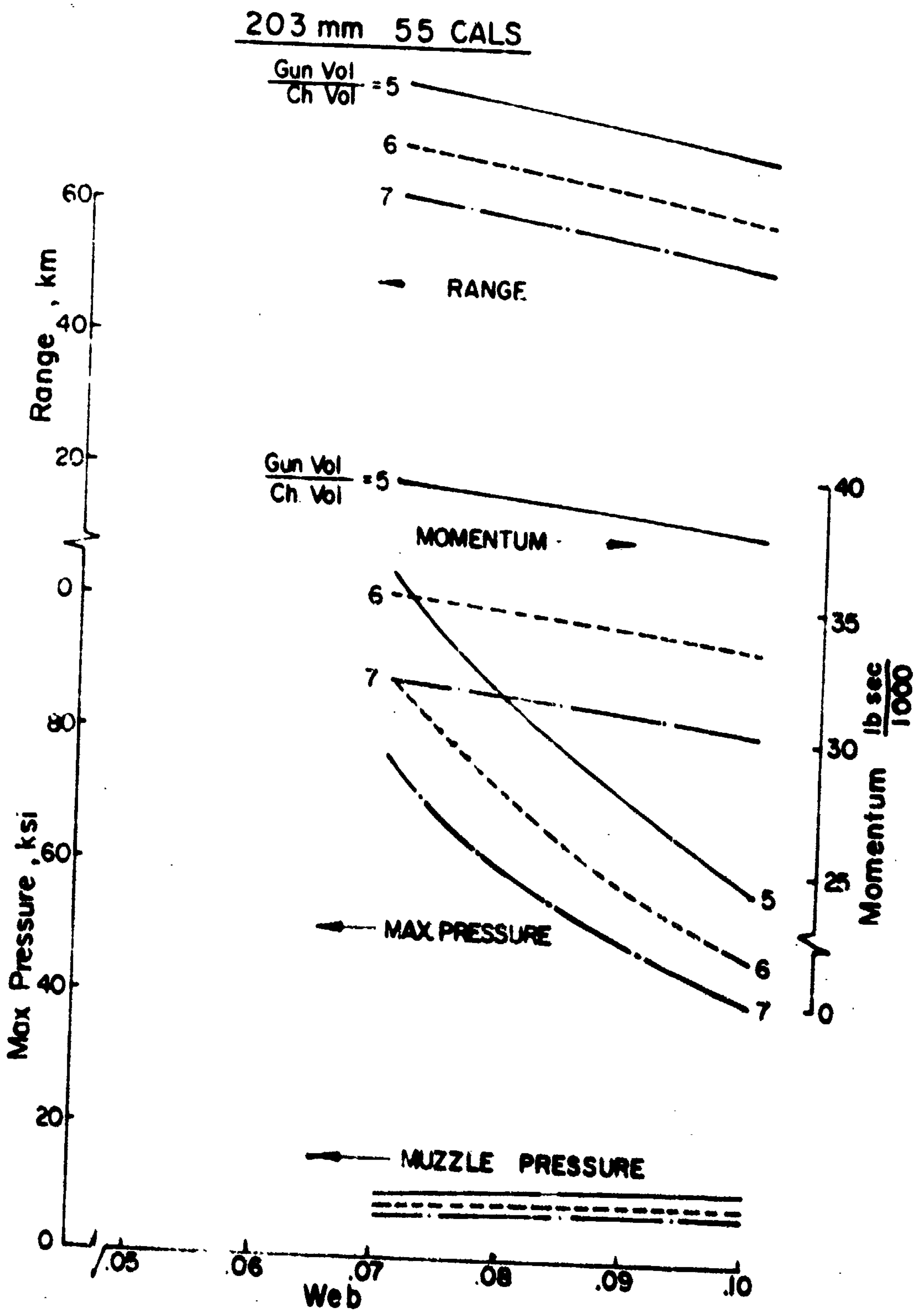
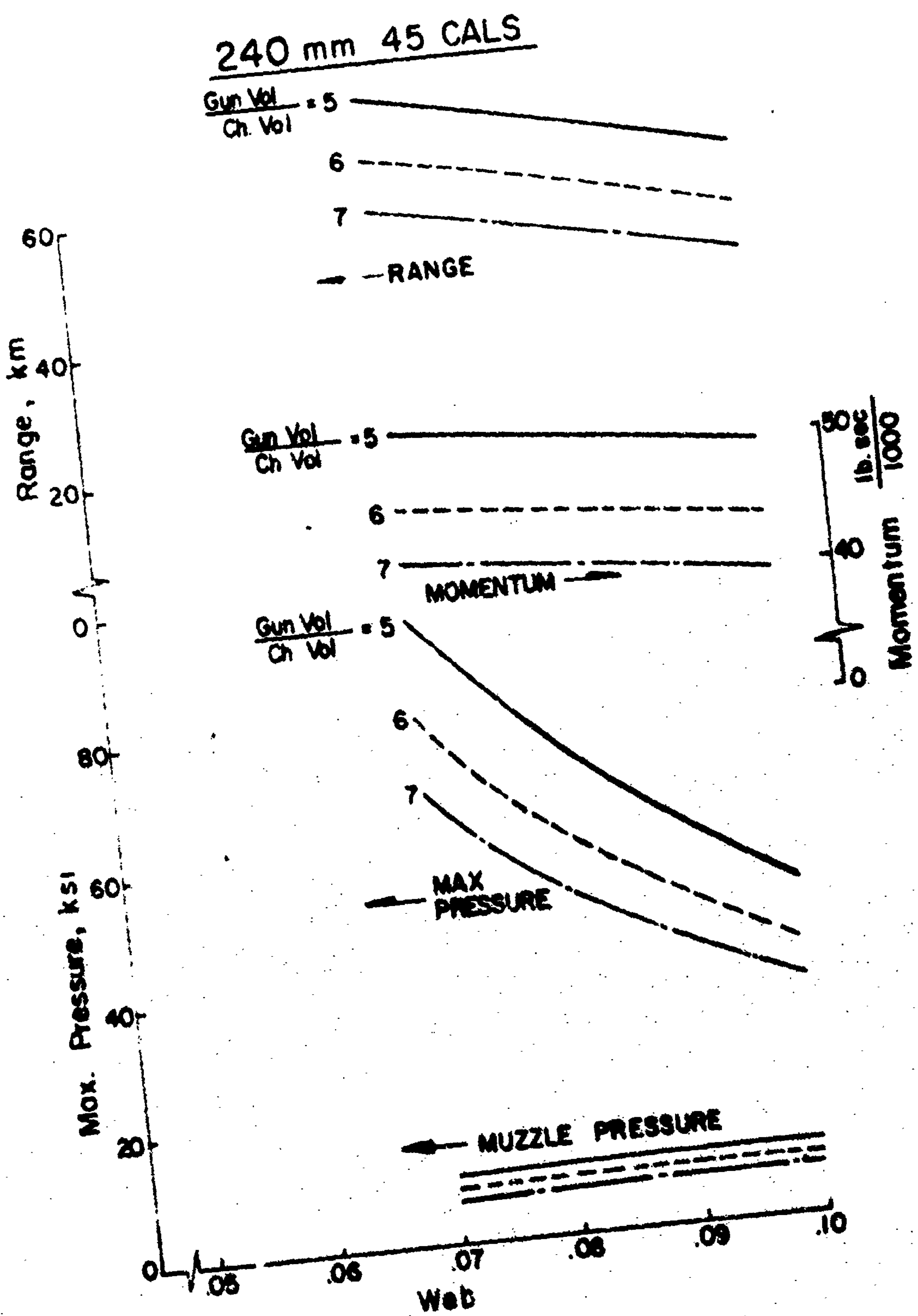
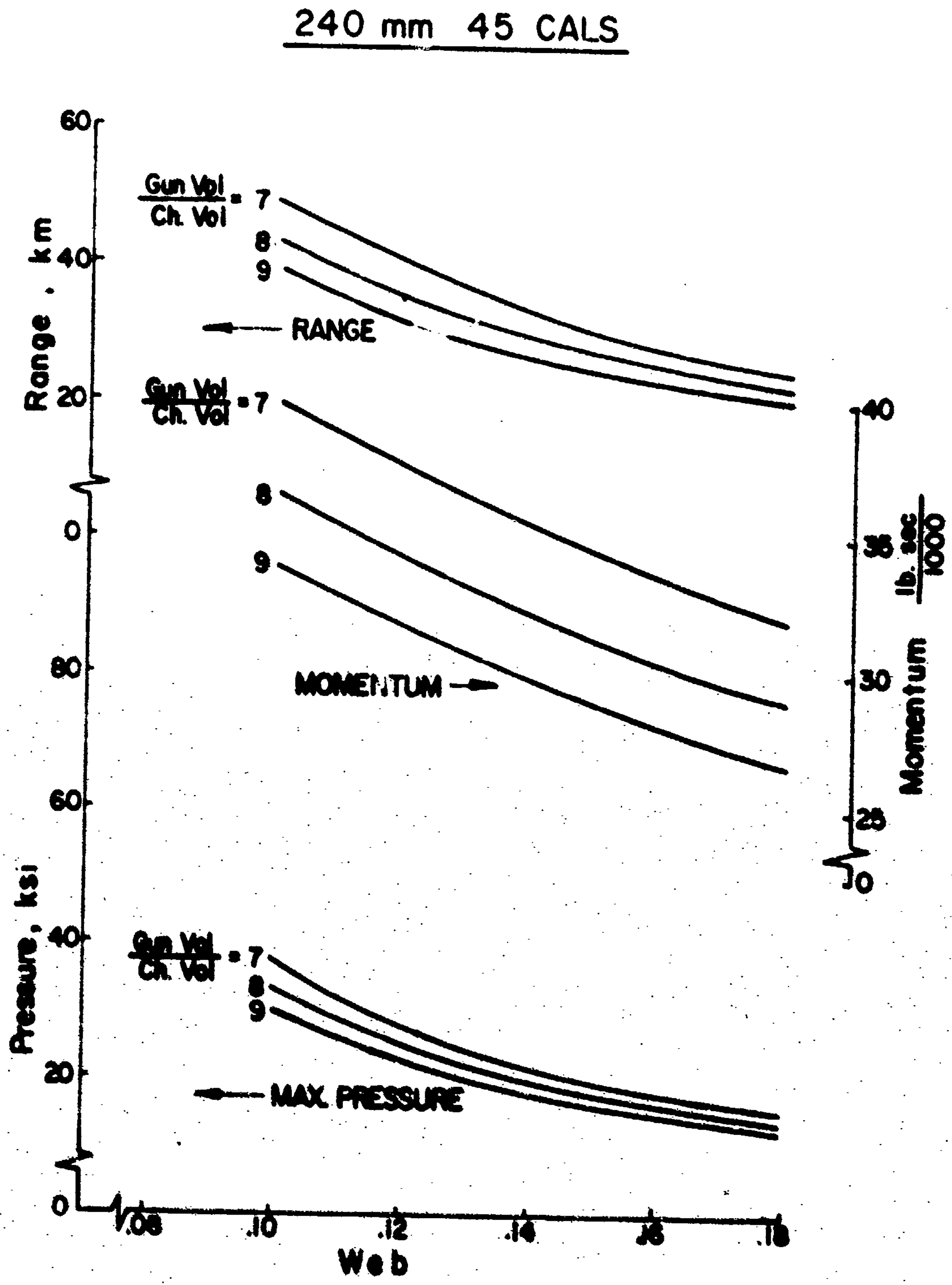

203 mm 55 CALS
Gun Vol / Ch Vol = 5
6
7
RANGE
Range , km
60
40
20
Gun Vol / Ch Vol = 5
MOMENTUM
6
7
5
6
7
MAX PRESSURE
MUZZLE PRESSURE
Max Pressure , ksi
0
80
60
40
20
0
40
35
30
25
0
Momentum lb sec / 1000
.05
.06
.07
.08
.09
.10
Web

Figure 10



240 mm 45 CALS
Gun Vol / Ch. Vol = 5
6
7
RANGE
Range, km
60
40
20
0
Gun Vol / Ch Vol = 5
6
7
MOMENTUM
Momentum lb. sec / 1000
50
40
0
Gun Vol / Ch Vol = 5
6
7
MAX PRESSURE
Max. Pressure, ksi
80
60
40
20
0
MUZZLE PRESSURE
.05
.06
.07
.08
.09
.10
Web

Figure 11



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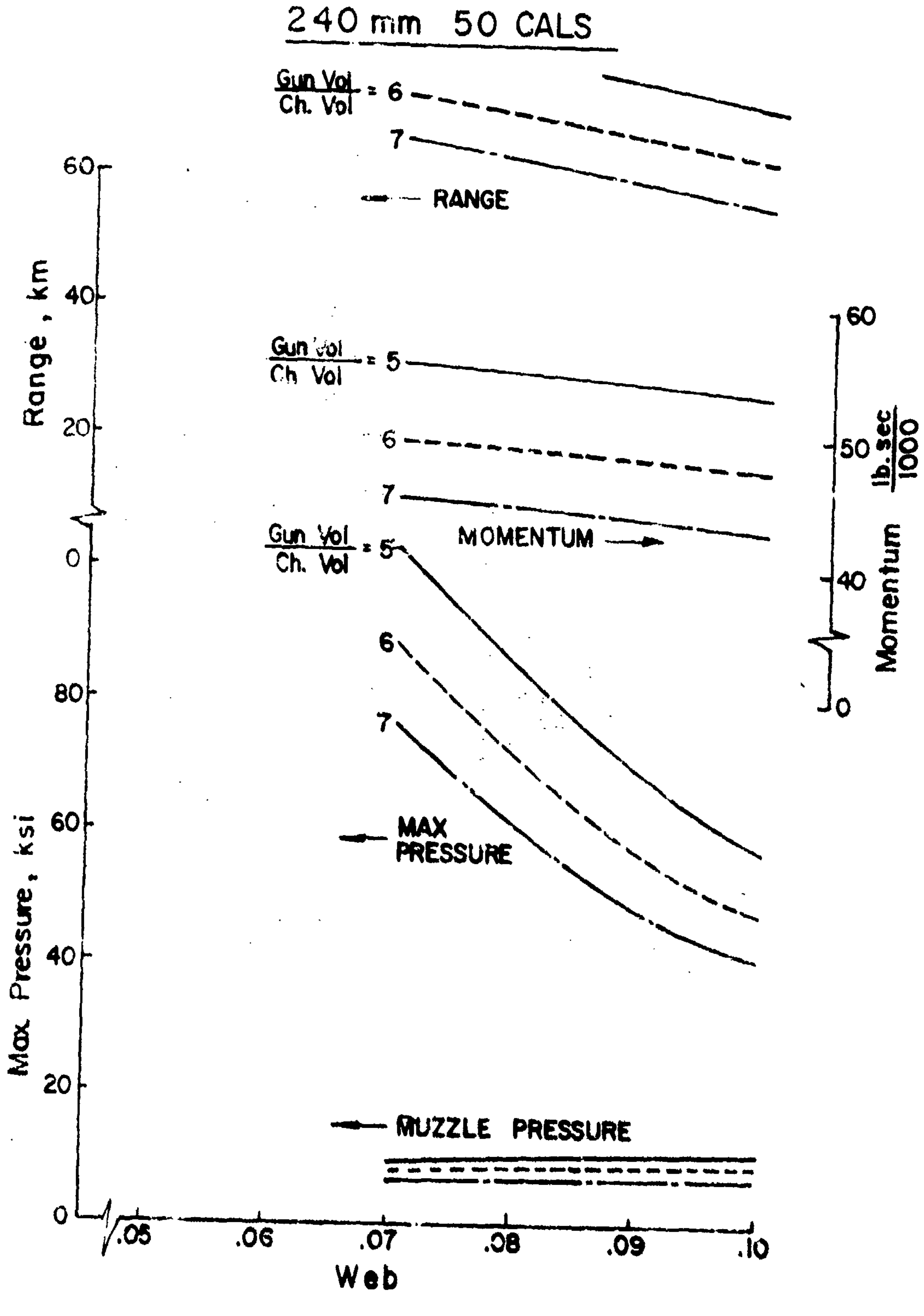
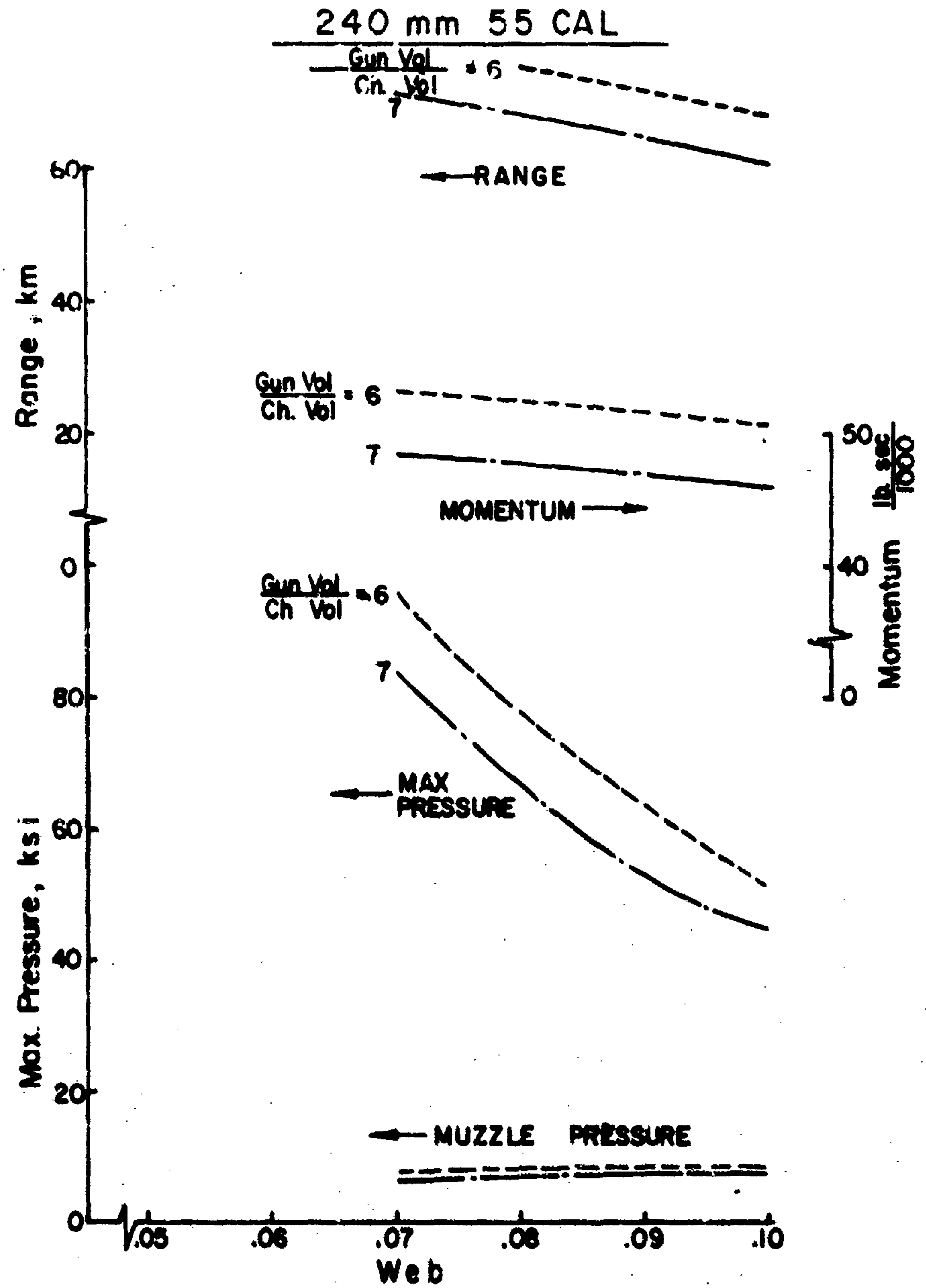

240 mm 50 CALS
Gun Vol / Ch. Vol = 6
7
RANGE
Range, km
60
40
20
0
Gun Vol / Ch. Vol = 5
6
7
MOMENTUM
Momentum lb.sec / 1000
60
50
40
0
Gun Vol / Ch. Vol = 5
6
7
MAX PRESSURE
Max. Pressure, ksi
80
60
40
20
0
MUZZLE PRESSURE
.05
.06
.07
.08
.09
.10
Web

Figure 12



240 mm 55 CAL
Gun Vol / Cn. Vol = 6
7
RANGE
Range, km
60
40
20
0
Gun Vol / Ch. Vol = 6
7
MOMENTUM
50
40
0
Momentum lb sec / 1000
Gun Vol / Ch Vol = 6
7
MAX PRESSURE
Max. Pressure, ksi
80
60
40
20
0
MUZZLE PRESSURE
.05
.06
.07
.08
.09
.10
Web

Figure 13

$$\text{Towed Wt} = 311.92 + .36788\,(10^{-2})\,(ME) - .6544\,(MOM) - 1.8317\,(ME)\,(MOM)\,10^{-8}$$

Where WT = lbs

ME = ft lbs of muzzle energy

MOM = lb-sec of momentum

Admittedly, the negative constant appears to be erroneous by implying a negative weight when the independent variables vanish. This simply means that the relationship does not apply at small values of those variables; good correlation does not occur until approximately 13,000 lbs is reached. The 155mm XM198 is an exception, but this is an extremely light system by conventional standards. This is reflected in these results.

The following, Table 3, shows the data on which the expression is based. It also includes the observed weight and the weight predicted by the regression equation.

TABLE 3

WEAPON WEIGHT CORRELATION DATA

WEAPON	ME		MOM.	OBSERVED WT.	PREDICTED WT.
75mm How M116	.3567(10^6)		712	1,440	530
105mm How M101A1	1.231	(10^6)	2,000	4,980	2,863
105mm How M102	1.346	"	2,074	3,000	3,233
155mm How XM198	7.435	"	9,600	14,600	19,450
155mm How M114A1	5.049	"	7,383	12,700	12,745
155mm Gun	11.565	"	12,765	31,590	31,175
8" How M115	11.809	"	16,218	29,700	29,010
240mm How	29.571	"	37,355	64,700	63,800
8" Gun	30.270	"	34,710	69,500	69,090
280mm Gun M65	58.230	"	69,488	94,000	94,315

The results are further illustrated by Figure 14 which is a plot of Predicted vs. Observed weights. The vertical distance of the points from the 45° line shows the error.

Inspection of the ballistic output and curves will show that many options are included which are not practical, mostly because of large momentum. Their inclusion in the table means only that they are ballistically feasible. In this way, inspection can be used to discard many options and make digestion of the data a little easier.

The big problem from this point forward will be to devise a means of using the data produced. Some minor considerations or a desire to look at sabot combinations may require the generation of more data,

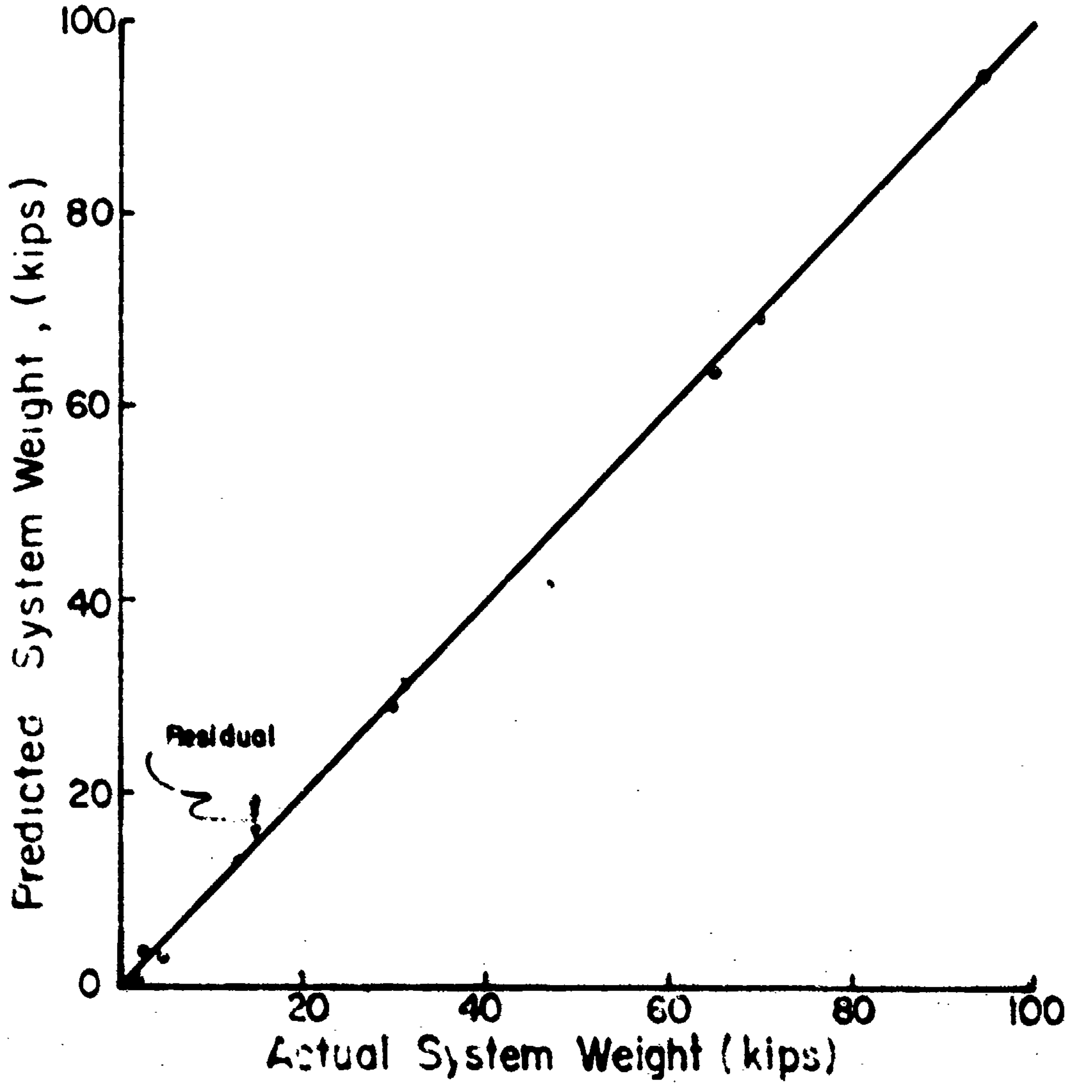

100
80
60
40
20
0
20
40
60
80
100
Predicted System Weight, (kips)
Actual System Weight (kips)
Residual

Figure 14

but this is no problem except that it makes the analysis of the data that much more difficult.

Future work will be directed toward a solution of this problem and the selection of the best option. As coordination with Picatinny Arsenal and Rodman Laboratory proceeds, more data may be required and, if so, this will also be produced. It may well be that final selection will be based on the imposition of realistic limits on parameters such as already described for the pressure and momentum limitations.

One final observation about predicted vs. actual weights is in order. Note in Table 3 that there is a rather large residual error for the 155mm Howitzer XM198. Also, it is in the favorable direction; i.e., the actual or observed weight is less than that predicted. A reason for this is that this system is our most modern approach and uses several weight saving techniques, e.g., muzzle brakes. This means that our predictive equation tends to be conservative and that we can now produce systems lighter than what would be expected from that model.

REFERENCES

1. R. A. Reisman, J. S. Pordon, G. T. French, "The Potentials of Fin Stabilized Artillery Munitions," Report SAS 154, April 1973, Picatinny Arsenal.

APPENDIX

DETAILED BALLISTIC OUTPUT

MAX. PRESS. (KSI)	MUZZLE VELOCITY (FPS)	MUZZLE PRESS. (KSI)	[illegible] (IN)	CHARGE WT. (LBS)	CHAMBER VOL. (IN³)	TRAVEL (IN)	GUN VOL. / CHAMB. VOL.	BARREL LENGTH (CALS)	MOMENTUM (LB-SEC)	RANGE (KM)
72.4	2930	11.6	.07	37.08	1710	234	5	45	16,980	46.0
56.9	2880	12.2	.08	"	"	"	"	"	16,600	42.6
46.3	2770	12.6	.09	"	"	"	"	"	16,170	39.5
32.3	2650	13.1	.10	"	"	"	"	"	15,710	36.0
60.2	2770	9.4	.07	30.57	1410	241	6	45	15,210	39.2
47.5	2670	9.8	.08	"	"	"	"	"	14,840	36.6
39.[illegible]	2560	10.3	.09	"	"	"	"	"	14,420	33.4
33.0	2450	10.7	.10	"	"	"	"	"	13,970	30.2
51.7	2600	7.2	.07	26.00	1200	246	7	45	13,870	34.5
41.2	2500	8.2	.08	"	"	"	"	"	13,500	31.7
34.1	240[illegible]	8.6	.09	"	"	"	"	"	13,100	29.1
29.0	22[illegible]0	9.1	.10	"	"	"	"	"	12,650	26.8
79.7	3170	11.3	.07	41.21	1901	260	5	50	18,310	52.9
63.1	3070	11.8	.08	"	"	"	"	"	17,940	49.4
51.0	2970	12.2	.09	"	"	"	"	"	17,540	45.9
42.6	2850	12.7	.10	"	"	"	"	"	17,100	42.0
66.7	2950	9.1	.07	33.97	1567	268	6	50	16,390	44.9
52.3	2850	9.5	.08	"	"	"	"	"	16,030	42.0
42.8	2750	9.9	.09	"	"	"	"	"	15,630	38.9
36.0	2640	10.3	.10	"	"	"	"	"	15,200	35.3
57.0	2760	7.6	.07	28.90	1333	273	7	50	14,940	39.3
45.2	2670	8.0	.08	"	"	"	"	"	14,590	36.6
37.2	2570	8.4	.09	"	"	"	"	"	14,200	33.4
31.5	2460	8.7	.10	"	"	"	"	"	13,770	30.8

155MM BALLISTIC OUTPUT

MAX. PRESS. (KSI)	MUZZLE VELOCITY (FPS)	MUZZLE PRESS. (KSI)	WEB (IN)	CHARGE WT. (LBS)	CHAMBER VOL. (IN3)	TRAVEL (IN)	GUN. VOL. CHAMB. VOL.	BARREL LENGTH (CALS)	MOMENTUM (LB-SEC)	RANGE (KM)
36.6	3350	10.9	.07	45.33	2091	236	5	55	19,600	56.8
69.3	3250	11.4	.08	"	"	"	"	"	19,240	55.7
55.8	3150	11.8	.09	"	"	"	"	"	18,850	52.1
46.4	3040	12.2	.10	"	"	"	"	"	18,420	48.3
72.9	3110	8.8	.07	37.37	1724	295	6	55	17,530	50.3
57.3	3020	9.2	.08	"	"	"	"	"	17,180	47.3
46.6	2920	9.6	.09	"	"	"	"	"	16,790	44.3
39.1	2820	10.0	.10	"	"	"	"	"	16,380	40.9
62.5	2920	7.4	.07	31.76	1466	301	7	55	15,980	44.3
49.2	2830	7.7	.08	"	"	"	"	"	15,630	41.4
40.4	2730	8.0	.09	"	"	"	"	"	15,250	38.3
34.1	2630	8.4	.10	"	"	"	"	"	14,840	35.1

155MM BALLISTIC OUTPUT

[illegible]	VELOCITY (FPS)	PRESS. (KSI)	WEB (IN)	WT. (LBS)	VOL. (IN3)	TRAVEL (IN)	GUN VOL. / CHAMB. VOL.	LENGTH (CALS)	MOMENTUM (LB-SEC)	RA (K
[illegible]	3560	[illegible]	.07	83.31	3843	306	5	45	34,260	63
[illegible]	[illegible]	11.4	.09	"		"	"	"	33,640	60
[illegible]	3350	11.9	.09	"	"	"	"		32,970	56
[illegible]	3240	12.3	.10	"	"	"	"		32,250	52
73.[illegible]	3310	[illegible]	.07	68.68	3169	316	6	"	30,580	55
57.7	3210	9.2	.08	"	"	"	"	"	29,980	51
46.9	3110	9.6	.09	"	"	"	"	"	29,320	48
33.3	2930	10.0	.10	"	"	"	"	"	28,620	44
[illegible]	3110	7.4	.07	52.42	[illegible]	322	7	"	27,820	48
43.[illegible]	3010	7.7	.08	"	"	"	"	"	27,230	45
40.6	2910	8.1	.09	"	"	"	"	"	26,590	42
34.[illegible]	2800	8.4	.10	"	"	"	"	"	25,900	38
25.9	2550	9.0	.12	"	"	"	"	"	24,350	31
20.6	2300	8.1	.14	"	"	"	"	"	22,780	26
17.1	2090	6.7	.16	"	"	"	"	"	21,500	22
14.5	1920	5.7	.18	"	"	"	"	"	20,490	20
30.6	2640	7.4	.10	[illegible]	2345	327	8	"	23,800	34
23.3	2390	7.7	.12	"	"	"	"	"	22,260	28
18.6	2150	6.7	.14	"	"	"	"	"	20,760	23
15.5	1960	5.6	.16	"	"	"	"	"	19,570	20.
13.2	1800	4.7	.18	"	"	"	"	"	[illegible],620	19.
27.[illegible]	2500	6.5	.10	44.98	2075	331	9	"	22,080	30.
21.2	2250	6.7	.12	"	"	"	"	"	20,550	25.
17.1	2020	5.7	.14	"	"	"	"	"	19,120	21.
14.2	1840	4.7	.16	"	"	"	"	"	18,010	19.
12.1	1700	[illegible]	.18	"	"	"	"	"	17,120	18.

203MM BALLISTIC OUTPUT

[illegible]	MUZZLE [illegible]	MUZZLE PRESS. (KSI)	WEB (IN)	CHARGE WT. (LBS)	CHAMBER VOL. (IN^3)	TRAVEL (IN)	GUN VOL. / CHAMB. VOL.	BARREL LENGTH (CALS)	MOMENTUM (LB-SEC)	RANGE (KM)
[illegible]	[illegible]	[illegible]	.07	[illegible]	4270	340	5	50	36,930	71.3
[illegible]	[illegible]	11.9	.08	"	"	"	"	"	36,340	68.1
[illegible]	[illegible]	11.4	.09		"	"	"	"	35,700	64.7
[illegible]	[illegible]	11.[illegible]	.10	"	"	"	"	"	35,010	60.5
[illegible]	[illegible]	[illegible].5	.07	76.31	3520	351	6	"	32,940	62.4
[illegible]	[illegible]	[illegible]	.08	"	"	"	"	"	32,370	59.0
[illegible]	[illegible]	[illegible]	.09	"	"	"	"	"	31,740	55.4
[illegible]	3210	[illegible].6	.10	"	"	"	"	"	31,060	51.8
[illegible]	3300	7.[illegible]	.07	64.91	2996	358	7	"	29,950	54.9
[illegible]	3200	7.5	.08	"	"	"	"	"	29,380	51.8
44.[illegible]	3110	7.[illegible]	.09	"	"	"	"	"	28,770	48.3
[illegible]	3000	[illegible].1	.10	"	"	"	"	"	28,100	45.0
[illegible].1	2760	[illegible].3	.12	"	"	"	"	"	26,600	37.3
[illegible]	[illegible]	[illegible].5	.14	"	"	"	"	"	25,000	30.5
[illegible]	2290	7.1	.16	"	"	"	"	"	23,610	25.8
[illegible]	[illegible]	6.[illegible]	.18		"	"	"	"	22,500	22.7
33.[illegible]	2630	7.[illegible]	.10	56.48	2605	364	8	"	25,810	39.5
[illegible]	2590	7.6	.12	"	"	"	"	"	24,330	32.8
[illegible]	2340	7.1	.14	"	"	"	"	"	22,780	27.0
16.7	2130	5.9	.16	"	"	"	"	"	21,480	23.2
[illegible]	1960	5.0	.18	"	"	"	"	"	20,440	21.1
[illegible]	2630	6.[illegible]	.10	49.92	2306	368	9	"	23,960	35.3
[illegible]	[illegible]	6.7	.12	"	"	"	"	"	22,480	29.2
[illegible]	[illegible]	6.1	.14	"	"	"	"	"	20,980	24.5
15.[illegible]	[illegible]	5.6	.16	"	"	"	"	"	19,760	21.3
13.[illegible]	1850	4.2	.18	"	"	"	"	"	18,790	19.7

203MM BALLISTIC OUTPUT

[illegible]	MUZZLE VELOCITY (FPS)	MUZZLE PRESS. (KSI)	WEB (IN)	CHARGE WT. (LBS)	CHAMBER VOL. (IN³)	TRAVEL (IN)	GUN VOL. / CHAMB. VOL.	BARREL LENGTH (CALS)	MOMENTUM (LB-SEC)	RANGE (KM)
[illegible]	397[illegible]	1[illegible]	.07	101.82	4697	375	5	55	39,530	78.6
[illegible]	3[illegible]	10.5	.0[illegible]	"	"	"	"	"	38,960	75.2
6[illegible]	37[illegible]	1[illegible].9	[illegible]	"	"	"	"	"	38,340	71.7
[illegible]	367[illegible]	11.3	.10	"	"	"	"	"	37,680	68.0
[illegible]	[illegible]	8.2	.07	93.94	3872	336	6	"	35,240	69.1
7[illegible]	[illegible]610	8.5	.08	"	"	"	"	"	34,670	65.7
[illegible].3	351[illegible]	[illegible].9	.09	"	"	"	"	"	34,060	62.4
47.[illegible]	341[illegible]	[illegible].2	.10	"	"	"	"	"	33,420	58.8
76.2	[illegible]	[illegible].9	.07	71.40	3294	334	7	"	32,020	61.2
6[illegible]	3390	7.[illegible]	.08	"	"	"	"	"	31,470	57.9
[illegible].6	3290	7.5	.09	"	"	"	"	"	30,870	54.8
40.7	3190	7.[illegible]	.10	"	"	"	"	"	30,220	51.2
3[illegible]	2950	8.5	.12	"	"	"	"	"	28,760	43.4
24.[illegible]	2700	8.6	.14	"	"	"	"	"	27,180	35.7
19.7	2460	7.5	.16	"	"	"	"	"	25,690	29.3
16.7	2260	6.4	.18	"	"	"	"	"	24,460	25.3

203MM BALLISTIC OUTPUT

[illegible]	MUZZLE VELOCITY (FPS)	MUZZLE PRESS. (KSI)	WEB (IN)	CHARGE WT. (LBS)	CHAMBER VOL. (IN3)	TRAVEL (IN)	GUN VOL. CHAMB. VOL.	BARREL LENGTH (CALS)	MOMENTUM (LB-SEC)	RANGE (KM)
[illegible]	[illegible]	10.4	.07	137.67	6351	36[illegible]	5	45	52,370	76.0
[illegible]	3900	10.8	.08	"	"	"	"	"	51,550	72.4
[illegible]	3780	11.3	.09	"	"	"	"	"	50,660	68.7
[illegible]	3670	11.7	.10	"	"	"	"	"	49,700	64.5
[illegible]	3720	8.4	.07	113.49	5236	373	6	"	46,620	66.5
[illegible]	3620	8.8	.08	"	"	"	"	"	45,810	63.2
51.[illegible]	3510	9.2	.09	"	"	"	"	"	44,940	59.4
43.[illegible]	[illegible]	9.6	.10	"	"	"	"	"	44,000	55.5
6[illegible].4	3500	7.1	.07	96.[illegible]	4454	381	7	"	42,330	59.0
54.[illegible]	3400	7.4	.08	"	"	"	"	"	41,530	55.6
44.[illegible]	32[illegible]	7.7	.09	"	"	"	"	"	40,670	52.3
37.[illegible]	3170	[illegible]	.10	"	"	"	"	"	39,700	48.2
[illegible]7.[illegible]	2920	[illegible].8	.12	"	"	"	"	"	37,640	40.2
22.[illegible]	2640	8.4	.14	"	"	"	"	"	35,440	32.8
1[illegible].[illegible]	2410	7.0	.16	"	"	"	"	"	33,530	27.5
15.5	2270	6.0	.18	"	"	"	"	"	32,010	24.2
33.1	3000	7.[illegible]	.10	83.99	3875	38[illegible]	8	"	36,450	42.7
25.[illegible]	2740	7.6	.12	"	"	"	"	"	34,390	35.4
20.[illegible]	[illegible]	7.1	.14	"	"	"	"	"	32,250	29.0
16.5	2260	5.8	.16	"	"	"	"	"	30,470	24.8
14.[illegible]	2060	5.[illegible]	.18	"	"	"	"	"	29,050	22.2
30.[illegible]	[illegible]	6.2	.10	74.33	3429	391	9	"	33,800	38.2
22.[illegible]	2590	6.7	.12	"	"	"	"	"	31,740	31.5
18.3	2330	6.[illegible]	.14	"	"	"	"	"	29,680	26.0
15.2	2120	5.0	.16	"	"	"	"	"	28,010	22.7
12.9	1960	4.2	.18	"	"	"	"	"	26,680	20.5

240MM BALLISTIC OUTPUT

[illegible]	MUZZLE VELOCITY (FPS)	MUZZLE PRESS. (KSI)	WEB (IN)	CHARGE WT. (LBS)	CHAMBER VOL. (IN^3)	TRAVEL (IN)	GUN VOL. / CHAMB. VOL.	BARREL LENGTH (CALS)	MOMENTUM (LB-SEC)	RANGE (KM)
[illegible]	4140	10.0	.07	152.97	7057	403	5	50	55,800	81.0
[illegible]	4050	10.3	.08	"	"	"	"	"	55,020	77.6
[illegible]	3950	10.7	.09	"	"	"	"	"	54,220	74.2
[illegible]	3840	11.0	.10	"	"	"	"	"	53,340	70.8
[illegible]	3900	8.1	.07	126.10	5818	415	6	"	49,370	72.4
[illegible]	3800	8.4	.08	"	"	"	"	"	49,120	69.2
57.[illegible]	3700	8.7	.09	"	"	"	"	"	48,310	66.0
47.[illegible]	3600	9.1	.10	"	"	"	"	"	47,430	62.3
76.[illegible]	3690	6.8	.07	107.27	4949	423	7	"	45,420	65.5
[illegible]	3590	7.1	.08	"	"	"	"	"	44,670	62.3
48.[illegible]	3490	7.4	.09	"	"	"	"	"	43,850	59.0
[illegible]	3380	7.7	.10	"	"	"	"	"	42,980	55.2
111.4	4340	9.6	.07	168.26	7763	443	5	55	59,590	88.2
92.3	4250	9.9	.08	"	"	"	"	"	58,860	85.0
76.4	4150	10.3	.09	"	"	"	"	"	58,080	81.2
63.3	4050	10.6	.10	"	"	"	"	"	57,250	77.6
95.3	4090	7.8	.07	138.71	6399	456	6	"	53,250	79.1
77.7	4000	8.1	.08	"	"	"	"	"	52,520	76.0
63.0	3900	8.4	.09	"	"	"	"	"	51,740	72.4
51.8	3800	8.7	.10	"	"	"	"	"	50,900	69.0
83.5	3870	6.6	.07	117.99	5443	466	7	"	48,470	71.8
66.4	3780	6.8	.08	"	"	"	"	"	47,740	68.7
53.4	3680	7.1	.09	"	"	"	"	"	46,960	65.5
44.4	3580	7.4	.10	"	"	"	"	"	46,130	61.6

240MM BALLISTIC OUTPUT